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Patents Act 1990

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PROVISIONAL SPECIFICATION

Invention Title:

Feedthrough assembly

The invention is described in the following statement:

Field of the Invention

The present application relates to a device and method of making electrical feedthroughs, and more particularly to feedthroughs used in therapeutic implants.

Background of the Invention

The term 'feedthrough' as used herein refers to a structure used to provide electrical connections to a device having electrical circuitry disposed in a casing where it is desirable to maintain the circuitry in a hermetically sealed environment. A hermetic feedthrough is a device used to conduct electrical signals across a medium while at the same time acting as a barrier for the medium, preventing the ingress of any gases or liquids into or through the particular medium.

Historically, the first such devices were widely used in vacuum technology allowing for the transfer of signals between chambers of differing pressures. In such applications, the vacuum tubes had to be sealed because they could only operate under low pressure conditions.

Over time, other devices have also required a mechanism of allowing electrical connections between hermetically sealed circuitry and an external device. Perhaps the most obvious example of such devices are those used in medical implants to provide therapy to a patient, such as cardiac pacemakers, defibrillators and cochlear implants. As the environment of living tissue and body fluids is quite corrosive and the implants may contain materials which may be detrimental to the patient, a hermetic feedthrough device is used to provide a barrier between the devices electronics and the external corrosive environment of the human body.

In the early devices, such as those used in vacuum tubes, the feedthroughs were essentially made from glass plugs which were partly melted to allow electrical conductors to be passed therethrough. U.S. Pat. No. 4,678,868 is an example of a feedthrough developed for use in medical devices. Typically, such feedthroughs utilise a conductive pin to provide the

conductive path through the feedthrough and also include a ferrule which permits attachment of the feedthrough to the case, the conductive pin and a hermetic glass or ceramic seal which supports the pin within the ferrule and isolates the pin from the metal casing. This patent describes an alumina insulator to provide hermetic sealing and electrical isolation of a niobium conductor pin from a metal case. However, these types of feedthroughs have generally been not acceptable for use in medical implant applications because of the likelihood of deterioration.

Other materials and processes are known for making feedthroughs, for example, from aluminium oxide ceramic and binders. These types of feedthroughs are widely used for cardiac and cochlear implants. One of the processes for making such a feedthrough consists of pre-drilling holes in a sintered ceramic plate and then forcing electrical conductive pins through the holes. However, this method does not necessarily guarantee a hermetic seal. A second method involves inserting the conductive pins into an unsintered (or 'green') ceramic plate and then curing the assembly by firing to achieve a hermetic seal. A major disadvantage of this last method is that, historically this has been performed by hand. Such a method of manufacture can lead to inaccuracies and be time consuming, expensive and labour intensive. Moreover, the feedthrough devices resulting from such a process do not necessarily have precisely positioned electrical conductors. The position of the conductors being greatly dependent upon the process itself.

With the increase in the number of leads used for stimulation and sensory purposes in medical implant applications, the feedthrough requirements have also increased. In cochlear implants, where there are now typically 22-24 electrode leads, there is a need for 22-24 conductive pins passing through the feedthrough device. The problems in fabricating such a feedthrough device on such a large scale are therefore quite large, especially when one considers the relatively high degree of labour intensity and specialisation of the current fabricating methods.

The present invention aims to provide a feedthrough assembly which is capable of being mass produced, requires less specialist and intensive labour

resources, is more accurate, more reliable, less complex, and less expensive while still maintaining its hermeticity.

The present invention also aims to provide a feedthrough assembly that is capable of providing a more simplified connection between the hermetically enclosed electronic circuitry and any external components that are to be driven by such circuitry.

Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is solely for the purpose of providing a context for the present invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed in Australia before the priority date of each claim of this application.

Summary of the Invention

Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

According to a first aspect, the present invention is an electrical feedthrough comprising at least one layer of relatively electrically insulating material having a first surface and a second surface, the layer having at least one transverse intrinsic region extending through the layer between the first surface and the second surface that is electrically conducting relative to the electrical conductivity of the layer.

In one embodiment, the layer of material is a layer of material that can be rendered at least relatively electrically semiconducting in discrete regions.

For example, the layer can be a semiconducting crystalline material such as silicon (including high density silicon) or germanium. Other suitable materials that fall within this class, such as gallium arsenide, can also be

envisaged. The at least one transverse region can comprise a region of n-type or p-type semiconductor formed by appropriate doping of the layer with a suitable impurity in the region. In a preferred embodiment, the doping occurs at both the first and second surfaces to ensure that the low impedance electrically conducting region extends through the layer.

In another embodiment, the layer can be formed from an organic polymeric material that is normally electrically insulating but which can be rendered relatively electrically conducting by exposure to a suitable dopant anion. Intrinsically electrically conducting polymers, such as polyheterocyclics like polypyrrole, polythiophene and their derivatives, all fall within the scope of the invention.

In a further embodiment, the layer, such as a silicon wafer, can have a plurality of doped regions formed therein. In the case where the feedthrough is to be used in a cochlear implant having 22-24 electrodes, the layer preferably has 22-24 discretely doped regions extending from the first surface to the second surface.

The first and second surfaces can be planar and, if desired, parallel to each other. The layer can have any desired shape or dimension to meet the requirements of the application. For example, the layer can be circular, square or rectangular.

Additional layers can be formed on the first and second surface of the layer according to the present invention. The additional layers can be selected from the group consisting of silicon dioxide, SiO_2 + S1N1, P Glass and B Glass.

Conductive pads can be deposited on the first and second surface of the layer in the location of the electrically conducting regions. The conductive pads can be formed from a metallic material, such as gold, platinum or an eutectic alloy. Electrically conductive polymeric materials could also be utilised in this role.

Each conductive pad can have an electrically conductive wire connected thereto. Such wires can be formed from metallic materials or suitable

electrically conductive polymeric materials. The wires can extend to a circuit board or a stimulating electrode as the case may be. The wires can be bundled together or extend separately or in groups away from the feedthrough.

In a further embodiment, the layer can have a groove formed therein at the location of the relatively electrically conducting region. Such grooves can be formed in each surface of the layer. The grooves can be adapted to receive the electrically conductive wires and help retain them in place.

Mounting of the electrically conductive wires can be achieved through a number of bonding means, including soldering, gap welding, wirebonding and electrically conductive epoxies. Mechanical bonding techniques, such as crimping, can also be envisaged.

In another embodiment, instead of one side of the feedthrough being connected to electrical wire, active circuitry could be directly placed on the surface of the layer. This would allow a surface of the feedthrough device to form the chip of the electronic device containing the active circuitry in traditional methods and directly communicating to the other surface of the device through the electrically conducting intrinsic regions.

In use, the feedthrough device can be placed in the wall of a hermetic chamber. The hermetic seal between the device and the chamber wall can be formed by a suitable weld or braze. Other sealing techniques can also be envisaged.

Brief Description of the Drawings

By way of example only, a preferred embodiment of the invention is now described with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of a prior art feedthrough;

Figs. 2a and 2b are plan views of silicon wafers having doped regions for use as feedthroughs according to the present invention;

Fig. 3a is a cross-sectional view of one of the doped regions depicted in Figs. 2a and 2b;

Fig. 3b is a cross-sectional view of a doped region with deposited conductive pads depicted;

Fig. 4 is a plan view of a feedthrough with electrical leads depicted in position;

Fig. 5a is a cross-sectional view of another embodiment of a doped region according to the present invention;

Fig. 5b is a perspective view of a grooved recess formed in the surface of a silicon wafer and an electrical lead for mounting in this groove according to the present invention; and

Fig. 6 is a side elevation view of a feedthrough according to the present invention mounted in a hermetically sealed case.

Detailed Description of the Invention

As seen in Figure 1, the ceramic feedthrough device of the prior art as used in a cochlear implant application is a complicated device requiring a number of components carefully pieced together.

In simplified terms, a ceramic disc (1) is machined to appropriate dimensions of about 2.15 mm and has 28 holes (2) punched therethrough to accommodate each of 28 connector pins (3). Following the insertion of each of the connector pins (3) into each of the punched holes (2), the ceramic disc is further machined to provide grooves (4) as shown in figure 1. Following this the unit is then sintered to provide hermiticity to the ceramic disc assembly.

Following sintering, two titanium pads (5) are spot welded into the grooves (4) and a flange (6) is positioned and brazed around the ceramic disc assembly. The pins (3) are then dipped into a molten solder bath to ensure an even coating of solder and then formed into the radial position as shown in

figure 1. The heads of the pins (3) adjacent to the outer surface (7) are then attached to wires which are connected to electrodes (not shown) which are in turn inserted into the cochlea of a recipient to provide audible stimulation. The attachment of the head of the pin to the electrode wires is done by etching a V-shaped groove onto the surface of the pinhead and crimping and soldering the wire in place. The pins adjacent the inner surface of the device are attached to the internal circuitry via conventional soldering techniques.

As can be easily understood, the manufacturing process for the feedthrough device is both a complicated and time consuming process that requires much skill and effort in order to produce a feedthrough device of sufficient quality and reliability. Further to this, the process and device of the prior art requires at least one hole to be formed through the entire feedthrough device, further complicating the sealing process.

Figures 2a and 2b show two embodiments of the feedthrough device according to the present invention. The feedthrough device consists of a silicon wafer (10) having specific doped regions (11) arranged at intervals throughout the silicon wafer. The doped regions (11) extend through the silicon wafer (10) and provide a conductive path from one surface of the wafer through to the other surface, with the thickness of the silicon wafer being determined greatly by the application with which the feedthrough device is to be used as well as the limitations of the doping process. The conductive path is formed using conventional doping methods ensuring that the path is localised to a specific area within the silicon wafer. The device of the present invention overcomes the need to provide punched or drilled holes through the structure of the device for inserting conductive pins, thereby leaving the structure of the wafer intact. The device is, therefore, not a "feedthrough" device in the traditional sense of the word as there is no pin fed through the structure to provide a passageway connecting two mediums, rather the passageway utilises the conductive properties of the doped silicon to act in the same manner as previous inserted connector pins.

As can be seen in Figures 2a and 2b, the shape of the wafer/feedthrough device can be in any desired form from a circular shape as shown in Figure 2a to a square or rectangular shape as evident in Figure 2b. Other shapes of the

feedthrough device are also possible and fall within the general scope of the present invention.

Figures 3a and 3b show a cross-section of part of the feedthrough device of Figures 2a and 2b showing two examples of doped regions (11) according to the present invention. The doping is performed by conventional methods and occurs in localised regions (13) through the full thickness of the device. In order to ensure that the doping occurs through the full thickness of the wafer, the doping will be done on both sides of the wafer at the same position. As a result, the doped regions (11) act to provide virtual connector pins without the need for drilling and insertion of such pins and the subsequent problems associated with ensuring hermiticity. The present invention does not require drilling or punching of any holes through the feedthrough device.

The silicon wafer (10) can have surfaces (14) that are formed from a deposited coating, such as silicon dioxide, SiO_2 + S1N1, P Glass or B Glass in order to control the surface of the high density Silicon.

As shown in Figure 3b, it is possible to deposit conductive pads (15) on the surface of the silicon proximal to the doped regions (13). Such conductive pads (15) could be formed with any conductive material such as platinum, gold, or a eutectic alloy, with the pad (15) being formed to aid in the attachment of wires on either surface of the feedthrough device, as will be discussed in more detail below.

The number of conductive paths required by a feedthrough device according to the present invention is greatly dependant of the application with which the feedthrough device is being used. For example, a feedthrough device used in a cochlear implant would require at least 22 conductive paths to allow for connection of at least 22 stimulating electrodes to the implant circuitry. Other applications may not require as many paths, however it is an advantage of the present invention that such feedthrough devices can be made and customised to suit differing requirements with minimal changes in the manufacturing methods.

The feedthrough device of the present invention could be arranged as shown in Figure 4. In this embodiment, each of the doped regions (here depicted as 20) are connected by a wire (21) which would in turn be connected to a device such as a circuit board or a stimulating electrode. Each of the wires (21) could be bundled together in a common bundle (22) and branched off to singly connect to one surface of a doped region (20). Each of the doped regions (20) would typically be formed as depicted in Figure 3a or 3b with the surface of the doped region being formed to accommodate the attachment of the connecting wire. In the embodiment of Figure 3a, the surface of the silicon wafer itself would be grooved to accommodate the wire. The groove in the surface of the silicon would be in a direction/orientation dictated by the lattice structure of the silicon. In the embodiment of Figure 3b, the conductive pad deposit would also be provided with a groove in the surface to assist in the attachment of the wire. In both embodiments, the wires would then be firmly connected to the silicon surface or conductive pad deposit by any number of means, some of which will be described in more detail below.

It should be appreciated that similar connections would need to be made on each side of the feedthrough device so that the conductive path is able to transfer signals and the like from one medium to another. As there is no need to drill or punch a hole through the feedthrough device, hermiticity is maintained as there is a natural seal between the two mediums due in the main to the properties of the silicon wafer (10).

As previously discussed, the connecting wires could be attached to the doped regions of the silicon wafer by any number of means. In the embodiment of Figure 3b, where a conductive pad deposit is employed, such means could be traditional bonding means such as soldering, gap welding, wirebonding or via a conductive epoxy attaching the wire to the conductive pad deposit. Alternatively, the wires could be attached to the conductive pad deposit or the silicon surface via a mechanical means such as crimping or the like.

Two examples of such mechanical means will be described below and are shown in Figures 5a and 5b.

Figure 5a shows one particular method of attaching a wire (25) to a corresponding doped region (here depicted as 26). As can be seen, a groove (27) is made in the surface of the silicon above the doped region (26) and the wire (25) is then forced into this groove and bonded in place by any type of suitable "cold weld" method. By the term "cold weld" it is meant to incorporate any method of welding the wire to the silicon surface under high pressure or vacuum without the use of heat. This method of attachment does not require any soldering or welding and utilises physical forces to maintain the wire in place. The other end of the wire (25) could then be attached to a circuit board or electrode or any other suitable device depending upon the desired application.

Figure 5b shows another similar type method of attaching a wire (28) to a corresponding doped region of a feedthrough device according to the present invention. In this embodiment, a depression (29) is formed in the silicon wafer above a doped region in much the same way as in figure 5a. However in this particular embodiment, the wire (28) is held under tension and compressed into the formed depression (29) until it is engaged. The tension forces acting upon the wire force the wire into engagement resulting in an attachment that is purely mechanical and which does not require welding or the like.

It is considered that the method of attachment of the wires to the corresponding doped regions of the feedthrough device could be formed in any number of ways as understood by those skilled in the art and is not critical to an understanding of the present invention.

Following the attachment of the wires to both sides of the feedthrough device and completing the conductive path across the medium, the feedthrough device must be sealed so that hermeticity is maintained. Such a method of sealing is shown in Figure 6.

Figure 6 shows a feedthrough device of the present invention (depicted here as 31) positioned within a wall of a casing (30) of a device, for example the casing of an implanted stimulator unit such as those used in cochlear implants, pacemakers and the like. The casing may be made of titanium forming a hermetic shell around the implanted stimulator unit isolating the

internal circuitry and the like from the body fluids with which the unit is implanted. The feedthrough device has wires (33) attached to one side thereof, this side being enclosed by the titanium shell and being connected to the internal circuitry of the implanted stimulator unit. There are also corresponding wires (34) attached to the external surface of the feedthrough device which are connected to stimulating electrodes or the like (not shown) allowing the internal circuitry of the implanted stimulator unit to communicate directly with the stimulating electrodes or the like via the feedthrough device. In order to maintain a hermetic seal between the internal implanted circuitry and the environment of living tissue and body fluids, the feedthrough device is sealingly connected to the casing of the implanted stimulator unit by means of a suitable weld or braze. The weld/braze must be suitable to ensure a hermetic seal around the feedthrough device.

The present invention therefore provides a simple and effective way to provide a feedthrough device that is both easy to manufacture and requires less parts. The present invention also provides a feedthrough which would be of a reduced size and which could be manufactured by a truly automated process.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

DATED this twelfth day of March 2003

Cochlear Limited
Patent Attorneys for the Applicant:

F.B. RICE & CO.

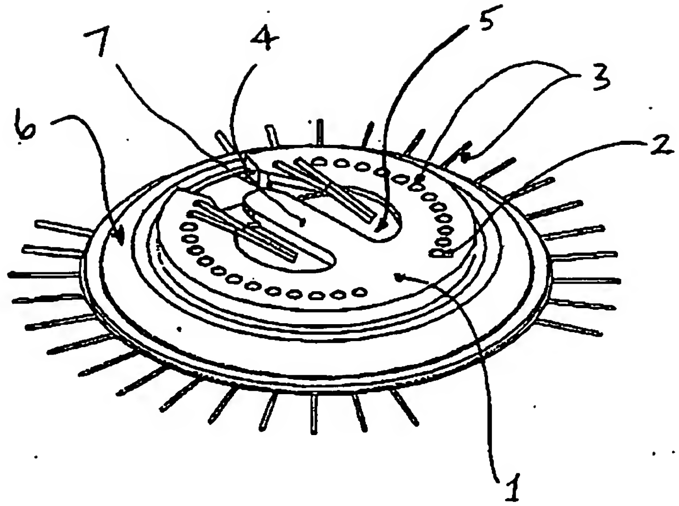

Figure 1

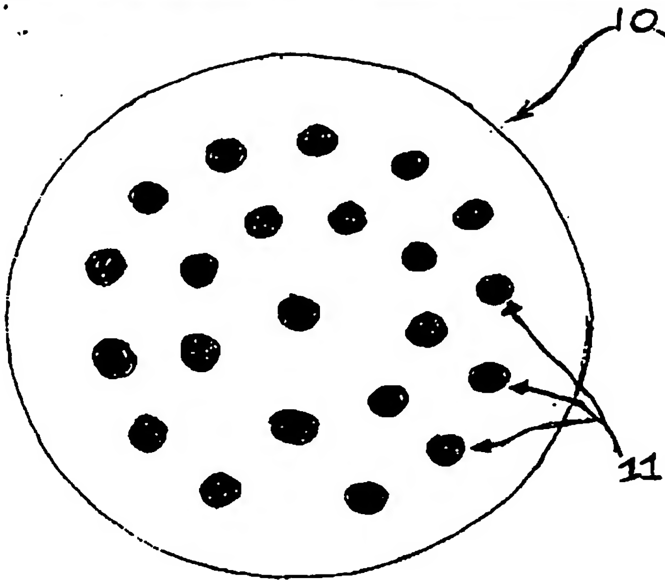

Figure 2a

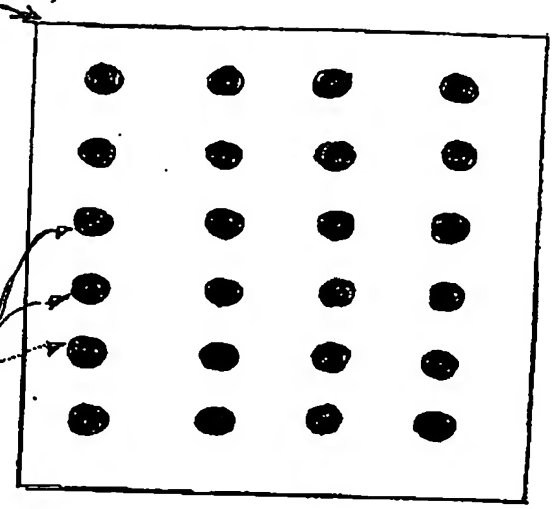

Figure 2b

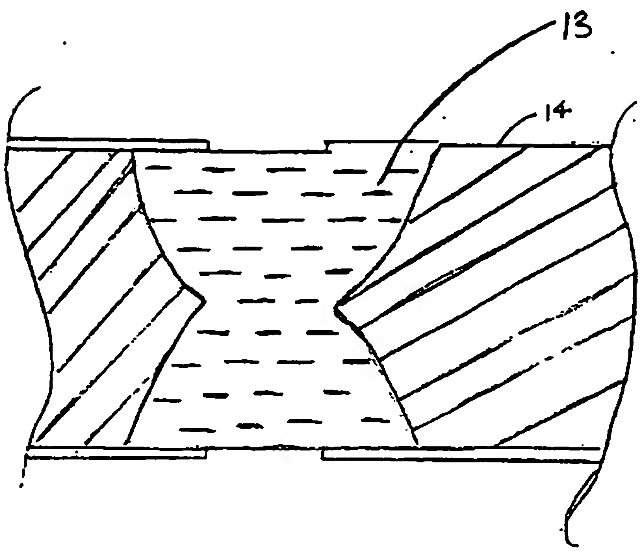

Figure 3a

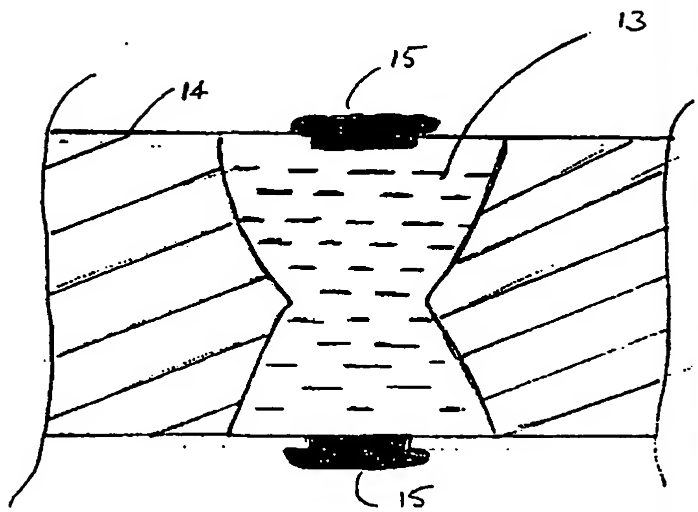

Figure 3b

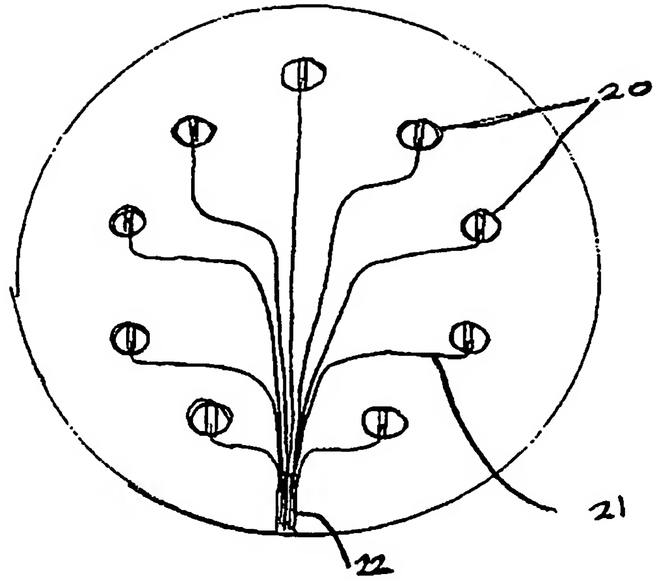

Figure 4

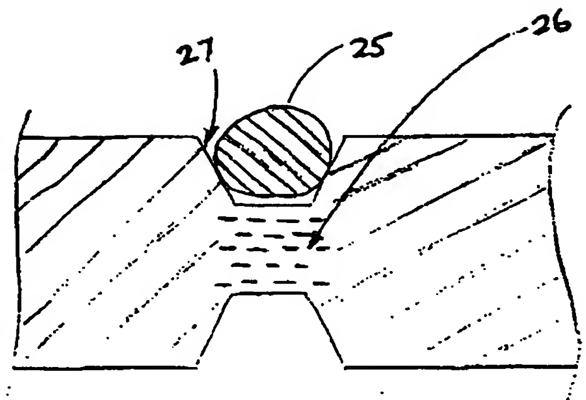

Figure 5a

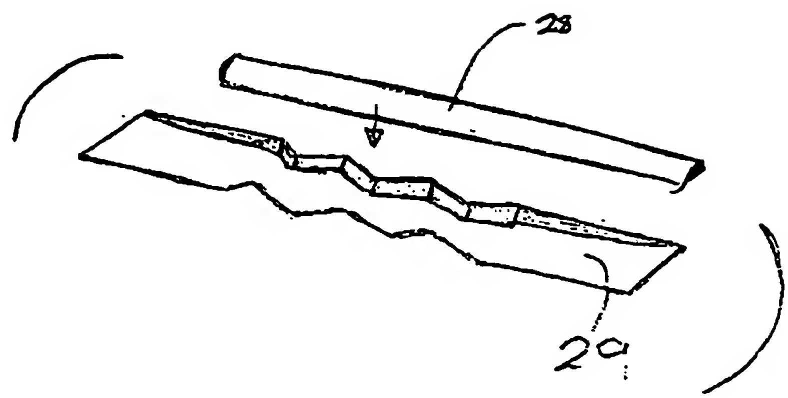

Figure 5b

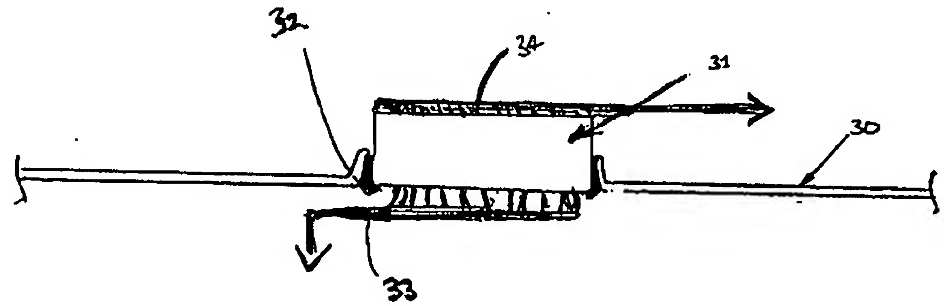

Figure 6